1. **Project Name:** **Development of Stronger and More Reliable Cast Austenitic Stainless Steels (H-Series) Based on Scientific Design Methodology**

2. **Lead Organization:** Duraloy Technologies, Inc.
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3. **Principal Investigator:** Mr. Roman Pankiw
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4. **Project Partners:**

Duraloy Technologies Inc., Contact: Mr. Roman Pankiw, (724) 887-5100 Ext. 188/ Fax: (724) 887-5224/ Email: techmgr@duraloy.com, DOE and In-kind: Overall project responsibility, alloy and property identification, casting trials, prototype assembly manufacturing and customer interfaces
Bethlehem Steel Corporation, Contact: Tony Martocci, In-kind: Identify applications, provide details of sizes needed, and implement prototypes in production conditions
The Timken Company, Contact: Mark F. Carlson, In-kind: Identify applications, property needs, size needs, and implement prototypes in production conditions
Energy Industries of Ohio, Contact: Bob Purgert, In-kind: Represents the alloy property needs of the chemical, steel, and heat treating industries of Ohio; assist in identifying components for each industry and implementing various solutions
Harper International, Contact: William Helfrich**,** In-kind: Provide design and location for installing prototype components; implement installation of components in Harper's designed production systems
IPSCO, Contact: Laurie Collins, In-kind: Input on detailed analysis of issues with the use of H-Series for current application and assist in solution implementation
NUCOR Steel Corporation, Contact: Robert Bennett, In-kind: Provide input on design specifications and locations for installation of prototypes, installing assemblies in production conditions, and inspect furnaces
Oak Ridge National Laboratory, Contacts: Vinod K. Sikka, and G. Muralidharan, DOE: Project coordination at ORNL, thermodynamic and kinetic modeling, alloy design and heat treatment, microstructural analysis, melting and processing of commercial-size heats, and mechanical properties

5. **Date Project Initiated and FY of Effort:** 03/31/2002, Fiscal Year 2003

6. Expected Completion Date: 03/31/2005

7. **Project Technical Milestones and Schedule:**

GOAL: The goal of the proposed program is to increase the high-temperature strength by 50% and upper use temperature by 30 to 60˚C of H-Series of cast austenitic stainless steels. Meeting such a goal will result in energy savings of 38 trillion BTUs/year and energy cost savings of $185 million/year.

OBJECTIVES: The main objective of this proposal is to use scientific and computational alloy development methods to modify existing HK and HP cast austenitic alloys by creating or controlling the microstructure that develops in specific components during service exposure. The combined application of micro-characterization of microstructure and computational phase prediction and its growth kinetics will be the key to meeting the objectives.

Tasks	**Task / Milestone Description**	**Planned Completion**
Task 1	Computational Thermodynamic Analysis of Various Phases in HK and HP Modified Steel	
	1.1 ThermoCalc™ analysis of phases for current HK and HP modified compositions in the cast, aged, and removed from service conditions	4/30/03
	1.2 ThermoCalc™ analysis of newly identified modifications of HK and HP modified compositions in the cast and aged conditions	10/31/04
Task 2	Micro-characterization of Specimens of HK and HP Modified for Verification of Computational Models and Correlation with Mechanical Properties	
	2.1 Micro-characterization analysis for current HK and HP modified compositions in the cast, aged, and removed from service conditions	10/31/03
Task 3	Cast Experimental Size Heats of New Compositions Developed Based on Tasks 1 and 2 and Determine Their Mechanical Properties	
	3.1 Melt 20-lb-size heats and cast into 1 × 4 × 6-in. slabs	4/30/03
	3.2 Conduct stress relaxation tests on cast compositions	10/31/03
Task 4	Centrifugal and Static Casting of Selected Compositions	
Task 5	Develop an Alloy Property/ Composition Predicting Software Tool for Commercial Applications	
Task 6	Fabricate Prototype Components	
Task 7	Meetings and Technical Reports	

8. **Past Project Milestones and Accomplishments:**

Past accomplishments, including achieved milestones are highlighted according to the tasks as shown below:

1. Computational Thermodynamic Analysis of Various Phases Present in HK and HP Modified Steel (Milestone 1.1 completed on schedule): This milestone deals with understanding the relationship between alloy composition and the phases present in the currently existing steels. Eight existing alloys have been selected and thermodynamic modeling of cast and aged conditions has been completed on these alloys using ThermoCalc^{TM}. In order to establish correlations between creep properties and phase constitution, these alloys were selected such that their creep properties varied significantly.
2. Microcharacterization of Current HK and HP Modified Steels, Verification of Computational Models, and Correlation with Mechanical Properties: Samples from eight alloys with varied creep properties were provided by Duraloy Technologies to ORNL. These alloys are being characterized using optical and electron microscopy techniques to evaluate the type of phases present, and their distribution within the microstructure. These results will be compared with completed ThermoCalc^{TM} predictions to learn trends.
3. Cast Experimental Size Heats of New Compositions Developed and Determine Their Mechanical Properties (Milestone 3.1 completed on schedule): Based on the information contained in the database and tasks 1 and 2, a series of ten alloys have been identified as an initial trial set for improved compositions. Eight of these alloys have been cast in the form of 20-lb heats, and machined into creep specimens. This constitutes the completion of the milestone. Creep tests on some of these alloys at two test conditions (982^{o}C, 4ksi), (1093^{o}C, 2 ksi)) have concluded while others are still continuing.
5. Develop an Alloy Property/Composition Predicting Software Tool for Commercial Applications: A neural network-based tool has been successfully experimented in learning the relationship between alloy composition and alloy properties. This tool has to be continuously improved over the remainder of the project and develop it into a tool for commercial applications.
7. Meetings and Reports: A major meeting with all partners was held Nov.13-14, 2002. In addition, frequent telephone conversations have taken place between Duraloy Technologies and ORNL. All quarterly and annual reports have been submitted.

9. **Planned Future Milestones:**

Plans for the future milestones for the fiscal year are given below as related to each task.

1. Computational Thermodynamic Analysis: Thermodynamic modeling using ThermoCalc^{TM} will be carried out as needed to fully characterize the phases present in newly developed compositions. Analyses have already been performed on four of the newly developed steel compositions, which is consistent with our schedules for our future proposed milestone. Complete analyses of the newly developed alloys will be performed by October 2004.
2. Microcharacterization of Specimens and Correlation, Verification of Computational Models and Correlation with Mechanical Properties (Milestone 2.1): Microstructural characterization of the newly developed compositions and creep tested specimens will be

continued to further validate ThermoCalc™ models to develop correlations between creep strength and phases present after solidication and during exposure to creep testing conditions. This milestone will be completed by October 31, 2003.

3. Casting Experimental Size Heats of New Compositions and Determining their Mechanical Properties: (Milestone 3.2) Based on the results of the on-going creep tests, predictions from ThermoCalc™, and microcharacterization, a new generation of alloys will be identified. These will be cast into experimental heats and their mechanical properties will be measured. The mechanical properties of the newly developed compositions will be completed by October 31, 2003.
4. Centrifugal and Static Casting of Selected Compositions: Two promising alloys from the developed experimental compositions will be centrifugally cast. Mechanical properties obtained from the centrifugally cast specimens will be compared with those obtained from the statically cast samples.
5. Development of Alloy Property/Composition Predicting Tool for Commercial Applications: Neural network based tools combined with Thermocalc™ will be used to learn and continuously update the relationship between alloy compositions and creep properties in the enhanced database. This will finally evolve into a predictive tool for commercial applications.
7. Meetings and Reports: A review meeting with all partners will be planned for July-August 2003. The meeting has been postponed to this date in order to present a more comprehensive picture regarding the creep properties to the project participants. Meetings between Duraloy Technologies Inc., ORNL, and other partners will continue as needed. Reports will be submitted as needed.

10. **Issues/Barriers:**

One of the issues associated with the project has been the limited amount of available creep data on existing alloys for very high temperatures (1000°C-1100°C) and a range of stress conditions relevant to this study.

11. **Intended Market and Commercialization Plans/Progress:**

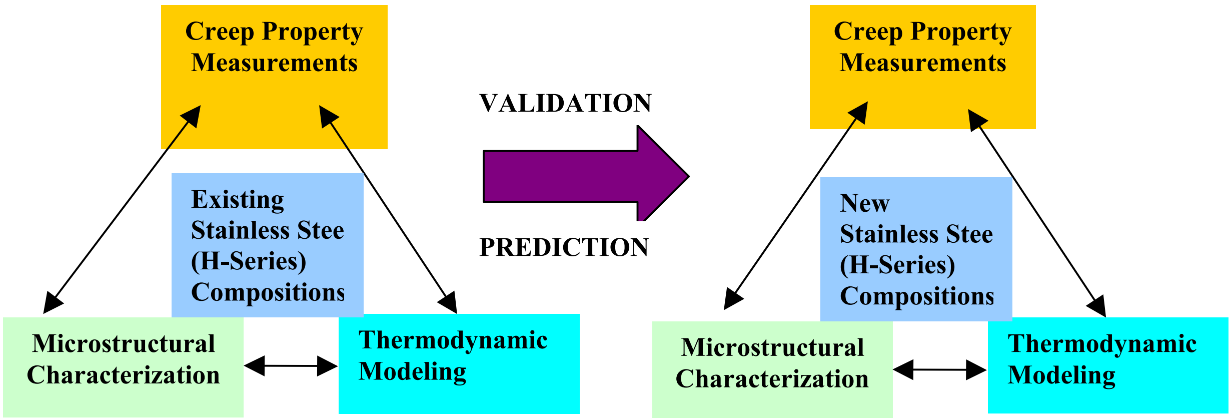
The end-use applications of these steels are in many of the IOFs. These include radiant burner tubes for annealing furnaces in steel heat treating industry, tubes for the chemical industry, transfer rolls for the steel industry, and kilns for various IOFs. Initial introduction of the new alloys in commercial applications is expected to be in the range of 10-100s of tons/year for each composition. Duraloy Technologies is one of the main producers of these steels and will implement this technology as it develops. The product of research will be alloy compositions, property data, and predicting tools for specific compositions. The outcome of the project is expected to have a significant impact on the steel, chemical, process heating and mining IOFs.

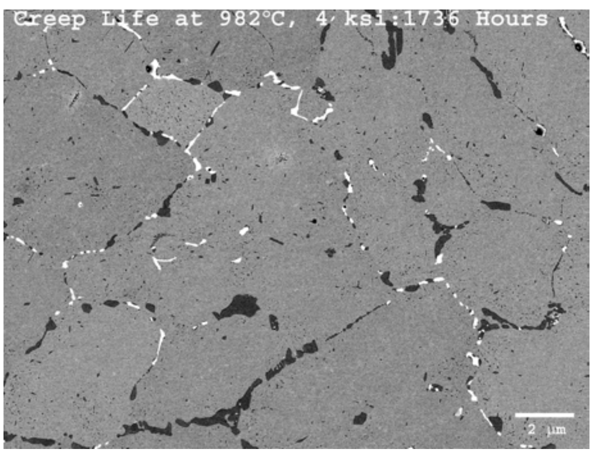
12. **Patents, publications, presentations:** None

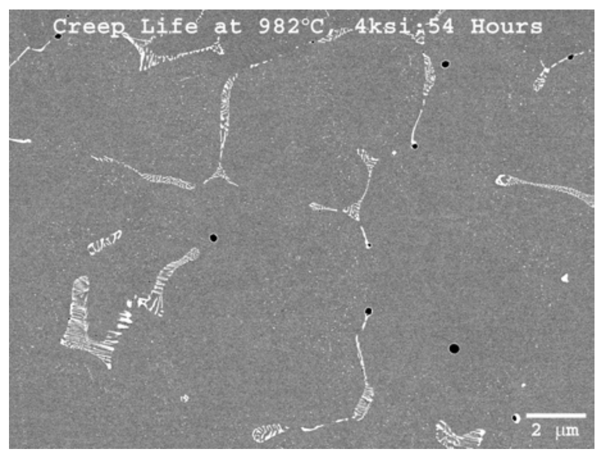
Highlight

OBJECTIVE: A new generation of cast Austenitic Stainless Steels (H-Series) with a higher use temperature than the currently available alloys will be developed through a scientific design methodology

APPROACH/RESULTS: The approach is based on three complementary sources of information as shown below







PHASE	PREDICTED MOLE. %
Matrix (Gray)	92.3
Nb Carbide (Bright)	1.0
$M_{23}C_6$ (Dark)	6.7

PHASE	PREDICTED MOLE. %
Matrix (Gray)	99.2
NbCarbide (bright)	0.8
$M_{23}C_6$	**0.0**

1. The type and volume fractions of the phases present in the alloys at the temperature of testing can now be successfully predicted.
2. Comparison of the microstructures shown above, and the results from the ThermoCalc™ calculations show that alloys with $M_{23}C_6$ significantly improved creep properties.

SIGNIFICANCE: Steels with improved creep properties developed as a result of this work will have a major impact on the IOFs. Higher operating temperatures will lead to more energy-efficient thermodynamic processes, and hence will result in energy savings and reduced costs through extended operating life.